Report for 2003MS16B: Improved Estimation of Nutrient and Pesticide Runoff Losses from Golf Courses and Residential Lawns in the South Atlantic-Gulf Region

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Report Follows

A Research Proposal Submitted to WRRI

(1) Title: Improved Estimation of Nutrient and Pesticide Runoff Losses from Golf Courses and Residential Lawns in the South Atlantic-Gulf Region

(2) Focus Categories: NPP, WQL, SW

(3) Keywords: water quality, rainfall-runoff processes; fertilizers, pesticides, nutrients

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(5) FY 2003 Federal Funds Requested:	$15,000 Total	($15,000) Direct	($0) Indirect
(6) Non-Federal (Matching) Funds Pledged:	$30,034 Total	($20,423) Direct	($9,611) Indirect

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(8) Congressional District: 3rd Congressional District

(9) Statement of Critical Regional Water Problems:

The ***Mississippi Water Research*** and ***South Atlantic-Gulf Region Water*** priorities addressed by this project are: the measurement and protection of surface water quality from nutrient and pesticide contamination (***Water Quality***), and predicting the rates of movement and concentrations of nutrients and pesticides to surface waters (***Contaminant Transport Mechanisms***).

Turfgrass is the most intensively managed biological system in metropolitan areas. Currently, over 40 million acres of turf are estimated to be growing in the U.S. If the areas of the approximately 15,0000 golf course were combined, they would encompass an area larger than Delaware and Rhode Island. An average of 350 new or expanded golf courses have opened each year since 1990, each averaging 150 acres. Following the national trend, turf acreage in Mississippi is expanding at a steady pace. Mississippi currently has an estimated 800,000 residential lawns comprising 300,000 acres and over 2,500 athletic fields. These figures do not include turf maintained at city parks, schools, churches, cemeteries, airports and industrial/commercial sites. An estimated 170 golf courses (ca. 15,000 A) and

175 sod farms (ca. 5000 A) are currently in operation in MS. In addition, about 2 million A of highway roadsides are maintained in Mississippi, a significant portion of which are treated with one or more herbicides each year. Turf-related agrochemical spending is expected to continue growing at 5.5% per year to 6.2 billion dollars by 2006. Unlike turf professionals, homeowners tend to apply more chemical than is necessary for effective results. As a result, the use of pesticides by homeowners may be as high as 5 to 10 lbs. per acre, almost ten times more chemical per acre than is used by farmers. The intensity of pesticide and nutrient use, coupled with the anticipated continued growth in turf acreage, suggests that concerns over the impacts of turf chemicals on surface water quality will likely increase over time.

Unfortunately, current models used to estimate nutrient and pesticide runoff from managed turf are not accurate, making it difficult to allocate between different sources of agricultural and non-agricultural contamination and to assess overall turf impacts on water quality. This project is designed to improve the estimation of nutrient and pesticide runoff from warm-season turf managed according to conditions found on golf course fairways and residential lawns.

(10) Statement of the Results, Benefits and Information Expected:

The expected results of our project are:

- Direct comparisons of the hydrology and nutrient and pesticide transport rates from warm-season turf grown to simulate golf course fairways (the largest treated areas on golf courses) and residential lawns (the largest segment of managed turf receiving pesticide and nutrient inputs).

- Determination of the scalability of runoff events from large and small treated areas for both residential and intensively managed turf.

- Improved simulation models used to estimate agrochemical runoff from warm-season turf.

By advancing the science of runoff estimation, our project will benefit surface water quality in the South-Atlantic-Gulf region as follows:

- Improved runoff estimation will allow the impacts of different turf maintenance regimes to be compared, greatly aiding in the development and targeting of practical, effective BMPs to reduce environmental impacts of agrochemical runoff from turf.

- Improved runoff estimation will enhance the ability of regulatory agencies to better allocate between agricultural and non-agricultural NPS loads, a key step in TMDL development.

- Improved hydrological models of warm-season grasses can be used to better predict the fates of oils and various inorganic contaminants washed onto grass from roadways, parking lots, etc.

- Improved runoff estimation will allow "what if" analysis and provide quantitative results to support rules/regulations for turf maintenance practices devised for a given watershed district.

- We anticipate that the real-world runoff scenarios generated by this project could be incorporated as sub-routines in BASINS and other watershed management programs to increase the accuracy of turf runoff estimations for mixed land-use watersheds.

(11) Nature, Scope and Objectives of Research

Turf Acreage & Agrochemical Use

Turfgrass is the largest, most intensively managed biological system in most metropolitan areas. In 1985, an estimated 3.6 million acres of turf were treated annually with agrochemicals[1] in the U.S. (Lin and Graney, 1992). More recently, a total of 30 to 40 million acres of turf were estimated to be growing in the U.S. (Hull et al., 1994; Emmons, 1995). Stuller (1997) reported that over 15,000 golf courses exist in the U.S., which if added together would encompass an area larger than Delaware and Rhode Island combined. An average of 350 new or expanded golf courses have opened each year since 1990, averaging 150 acres each (Stuller, 1997). Of this area, fairways comprise by far the largest percentage of intensively managed turf associated with golf course designs (Beard, 2000).

Following the national trend, turf acreage in Mississippi is expanding at a steady pace. Mississippi currently has an estimated 800,000 residential lawns comprising 300,000 acres and over 2,500 athletic fields (Wells, 2002). These figures do not include turf maintained at city parks, schools, churches, cemeteries, airports and industrial/commercial sites. The golf and sod-production industries, in particular, represent growth industries for the state. An estimated 170 golf courses comprising about 15,000 acres and 175 sod farms comprising about 5000 acres are currently in operation in Mississippi. In addition, the state of Mississippi maintains about 2 million acres of highway roadsides, a portion of which are treated each year with one or more herbicides (Wells, 2002).

Turf maintenance represents an important and growing market for pesticides and fertilizers. Turf-related agrochemical spending has grown steadily over the past decade and sales are expected to continue growing at 5.5% per year to 6.2 billion dollars by 2006 (Anonymous, 2002). Lawn care and landscape applications generally account for approximately 80% of the total treated turf area and 75% of total turf chemical expenditures (Lin and Graney, 1992). A survey conducted by the Minnesota Department of Agriculture (MDA) indicates that 90% of homeowners apply one or more lawn care products over the course of a growing season (MDA, 1998).

In terms of the *intensity* of use on a mass-per-unit-area basis, pesticide and fertilizer use on residential lawns often exceeds that of agriculture (Gold and Groffman, 1993; Farm Chemicals, 1992). This greater intensity of use is often attributed to the propensity of do-it-yourself applicators to apply, intentionally or unintentionally, more of chemical than recommend by product labels (Landscape Management, 2002). *As a result, the use of pesticides by homeowners may be as high as 5 to 10 lbs. per acre, about ten times more chemicals per acre used by farmers* (Mississippi State University Extension Service, 2001). The intensity of pesticide and nutrient use, coupled with the anticipated continued growth in turf acreage, suggests that concerns over the impacts of turf chemicals on surface water quality will likely increase over time.

Agrochemical Runoff from Turf

While agrochemical use in row crop agriculture has received significant attention as a contributor to surface water contamination, runoff from suburban/urban areas is increasingly recognized as a potential contributor to water quality impairment. Surface waters throughout the nation contain measurable concentrations of pesticides that result from non-agricultural applications (Larson et al., 1995). Wotzka et

[1] Agrochemicals include fertilizers, herbicides, fungicides, insecticides and growth regulators applied to protect turf from pests and/or to improve turf growth, density and appearance.

al. (1994) found runoff in Minneapolis, MN to contain the herbicides 2,4-D, MCPP and MCPA from April through October. The authors attributed early-season, low-level detections to commercial applications to lawns and gardens while the significantly higher herbicides concentrations detected in runoff later in the growing season were attributed to applications by individual homeowners. In contrast to runoff from agricultural fields where peak pesticide concentrations typically occur with the spring flush, detections in suburban/urban runoff have less distinct seasonal patterns and occur over a longer period of time (Larson et al., 1995). The increased duration of urban pesticide detections was attributed to the prolonged time frame during which homeowners apply pesticides to their lawns.

Pesticide and nutrient runoff from residential lawns has been indicated as a source of non-point source contamination in Mississippi (Mississippi Soil and Water Conservation Commission, 1995) that negatively impacts the Gulf of Mexico (Mississippi State University Extension Service, 2001). However, there is a distinct absence of data that determines the turf management system resulting in the greatest runoff losses. Runoff from golf courses has been investigated more than other turf settings due to public concerns over frequent pesticide use and the fact that many golf courses are designed such that runoff flows into ponds and creeks. Researchers measuring the runoff of pesticides from plots simulating greens and fairways have shown that, on average, about 7% of applied chemicals is lost as runoff when rainfall occurs = 48 h after application (Smith and Bridges, 1996; Hong and Smith, 1997; Armbrust and Peeler, 2002). This same trend holds true for NO_3-N losses (Linde and Watschke, 1997). Few studies have compared runoff losses between golf course and residential turf even though residential lawns represent a much higher percentage of land area than golf courses. As compared to professionally maintained golf courses, residential lawns may be especially prone to runoff due to soil compaction and other practices that limit the infiltration rate of rainfall and irrigation water (Harrison, 1993).

Management Differences between Golf Course Fairways and Home Lawns Affect Runoff Potential

A number of cultural differences exist between turf that is professionally managed for golf course fairways and home lawns. Key differences include mowing height and frequency, fertilization rate and frequency, aeration, and irrigation rate and frequency. Of particular interest are those factors that affect turf density. Welterlen et al. (1989) reported that shoot density is affected by soil moisture, N fertility, and mowing height.

Mowing height affects the number of grass plants per unit area (i.e., shoot density). Beard (1997) found that Bermuda grass was over 60% denser when mowed to a height of 0.5-inches as compared to a mowing height of 1.5-inches which had 300 shoots/dm^2. As shoot density increases, the water holding capacity (WHC) of underlying soil increases (Linde et al., 1995). Increased soil WHC reduces runoff losses. Typical mowing heights for residential lawns are 1 to 3 inches and 0.5 1.5 inches for golf course fairways. As a result, one could reasonably expect that differences in mowing height between golf course and home lawns could contribute to significant differences in runoff timing and volume.

A survey conducted in New Jersey indicates that over 80% of the pesticides applied to residential lawns are herbicides as compared to golf courses where 65% of all applications are fungicides (Anonymous, 1992). This indicates another significant difference between golf courses and residential lawns since herbicides are typically more water-soluble than fungicides and, as a general rule, more prone to runoff. Coupled with the propensity of homeowners to over-apply agrochemicals and the proximity of many residential lawns to streets and other impervious surfaces, runoff from treated lawns may quickly find its way to storm drains that are often directly linked to the nearest body of water.[2]

More information is needed to determine if turf maintenance practices contribute to surface water impairment in the south Atlantic-Gulf region, and to devise BMPs for agrochemical use on turf as has been done for agricultural settings. Currently there exists no regulatory exposure assessment tool that can be used by authorities at the Mississippi Department of Environmental Quality or and EPA Region IV to assess the impacts of various turf management scenarios on surface water quality.

Utility of Computer Models for Runoff Assessments

It is impractical to conduct runoff experiments exclusively on a site-by-site basis due to cost and logistical constraints. The only realistic approach is to use carefully calibrated and validated computer models to simulate the movement of nutrients and pesticides under different use scenarios. Model calibration first entails matching model output with the hydrology of the actual runoff event (i.e., timing and extent of water runoff). Next, the rate of transportation of a particular chemical is modeled by entering sorption coefficients, dissipation half-lives and other pertinent parameters so that the computer's results match actual runoff losses observed in the field. Once a computer model has been calibrated for a particular chemical under a given set of environmental conditions, the effect of different environmental conditions (e.g., normal vs. above-normal rainfall) on the runoff of that chemical can be determined. Alternatively, once the hydrology of a particular environment is matched, the model can be used to estimate the transport rate of different chemicals so as to rank their estimated mobility and subsequent concentrations in non-target aquatic systems. For these reasons, runoff models calibrated for various warm-season turf scenarios relevant to the South Atlantic-Gulf region would be valuable tools for regulators and environmental scientists in terms of assessing the fates of turf agrochemicals in Southeastern watersheds.

While there are a number of models used to predict NPS runoff of agrochemicals, the USEPA currently estimates pesticide runoff using a combination of models. The Pesticide Root Zone Model (PRZM) is used to estimate transportation rates and edge of field concentrations. The results of this model serve as inputs to EXAMS (Exposure Analysis Modeling System) that is used to determine the fates and concentrations of agrochemicals in aquatic systems. PRZM estimates daily runoff using the Soil Conservation Service (SCS) curve number technique. Runoff is calculated using a curve number and a continuous functional relation based on soil-water content in the root zone. Currently, regulators only have real world calibration scenarios for agricultural settings. Turf runoff is estimated using agricultural parameters due to deficiencies in turf runoff experiments.

Pesticide and nutrient runoff from agricultural fields can also be estimated using the Root Zone Water Quality Model (RZWQM). Like PRZM-EXAMS, RZWQM relies largely on agricultural settings to estimate runoff from fescue pastures (Ma et al., 1998). However, it is widely recognized that the use of agronomic parameters to estimate turf runoff results in inaccurate runoff estimations and, therefore, inaccurate assessments of potential impacts on water quality and non-target aquatic organisms. To fully determine the impact of turf agrochemical runoff on surface water quality, *real world* turf-specific modeling scenarios must be developed. To do this, critical data gaps must be filled by further experimentation.

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[2] Like residential lawns, runoff losses from commercial sod operations are essentially unknown. Because of the need for deep, fertile soils, commercial sod farms in Mississippi are often located on alluvial planes near streams and rivers. Currently, there is no information to assess the impacts of sod farms on surface water quality.

Data Requirements for Improved Turf Runoff Models

The United States Golf Association (USGA) has an interest in ensuring the accurate modeling of pesticide runoff from golf courses. Consequentially, the USGA has recently provided funding to support an effort to establish computer model scenarios for turf runoff that are relevant to the Southeast and Mid-Atlantic regions of the U.S. (*please see Appendix II for USGA letter*). The focus of the USGA project is the improved modeling of pesticide runoff from golf course turf. This issue is also of high interest to manufacturers of turf products (*please see Appendix II for supporting letter*). Runoff model refinements for the USGA study will address data gaps recently identified by the USEPA (Nett, 2002) which include (a) determining the scalability of pesticide runoff processes, and (b) determining the effect of warm-season grass species on pesticide runoff. Dr. Don Wauchope of the USDA-ARS is involved with our project as both a recognized expert in the measurement of field runoff and runoff modeling (*please see Appendix II for supporting letter*). An overview of the USGA-funded project is given below:

Overview of USGA-Funded Turf Pesticide Runoff Modeling Project

This collaborative project represents the first phase of a planned national "turf umbrella" project whose ultimate purpose is to improve understanding of regional differences in agrochemical runoff from turf. This project lays the necessary groundwork for collaboration with researchers at the University of Maryland and specifically seeks to bridge critical information gaps that currently prevent previous runoff research from being fully considered in pesticide risk assessments. The objectives of this project are (1) to develop a standardized field protocol for use in turf runoff experiments based upon input from key stakeholders, (2) to determine plot size effects on runoff (scalability) and (3) to determine warm-season grass species effects on the timing and extent of agrochemical runoff. These deficiencies, recently identified in a meeting held between the USEPA and turf industry representatives, ultimately prevent the accurate estimation of agrochemical runoff from turf since agronomic parameters/conditions are used in the absence of turf-specific information. This project will investigate the runoff of three pesticides having a range of physicochemical properties from replicated plots ranging from 0.01 to 0.1 acre in size. The plots will be planted with either hybrid Bermuda or Zoysia, with the Bermuda plots being over-seeded with ryegrass after dormancy to mimic a common management technique practiced in the Southeast that often increases fungicide applications for disease control. Key factors affecting runoff (e.g., antecedent moisture, soil properties, thatch content, hydraulic conductivity, soil bulk density) will be determined prior to initiating the simulated rainfall experiments.

An important aspect missing from the USGA study that is of significance to water quality issues in the Southern Gulf-Atlantic region is the modeling of nutrient runoff from golf courses and residential turf. Nutrients (nitrogen, phosphorus) are key contributors to surface water impairment in the Southern Gulf-Atlantic region. Moreover, lawns represent a greater portion of turf acreage than do golf courses and, therefore, may ultimately represent a greater source of contamination than golf courses. Unfortunately, few data exist to determine which of these turf management practices poses a more significant threat to surface water quality. Side-by-side comparisons between residential turf and turf maintained to golf course standards would help to establish the impact of turf runoff on water quality. *The funding and resulting infrastructure provided by the USGA represent a tremendous opportunity to develop an extensive regional database for nutrient and pesticide runoff from turf that goes beyond golf-course settings.* The objectives of the current project are given below:

Research Objectives

1. Determine rates of transport for nutrients (nitrogen, phosphorus) and pesticides applied to turf maintained according to USGA superintendent practices for fairways and turf maintained according to MSU Extension recommendations for home lawns. Statistically compare nutrient and pesticide runoff from the various turf management regimes.

2. Using results from Objective 1 to refine pesticide (PRZM) and nutrient (RZWQM) runoff model estimates for warm-season turf management regimes.

3. Compile turf-relevant hydrological parameters and contaminant transport rates for each turf maintenance regime/grass species into database for use by regulatory agencies and environmental engineers/scientists.

(12) Methods, Procedures and Facilities

Objective 1: Determine rates of transport for nutrients (nitrogen, phosphorus) and pesticides applied to turf maintained according to USGA superintendent practices for fairways and turf maintained according to MSU Extension recommendations for home lawns. Statistically compare nutrient and pesticide runoff from the various turf management regimes.

Three pesticides having a range of chemical properties (i.e., K_{OC} and water solubility) will be selected and applied simultaneously to allow modeling of a range of pesticide behaviors. Chemical fertilizers will be applied according to standard USGA practices for fairways and MSU recommendations for home lawns, as appropriate. The runoff parameters known to affect runoff that will be collected are given in **Table 1** below:

Soil & Thatch Factors	***Climatic Factors***
Saturated. hydraulic conductivity (k_{sat})	Precipitation at 5-min intervals
Soil texture	Air/soil temp at 5-min intervals
OC content of soil and thatch	Solar radiation
Soil Bulk density	Wind speed at 2-m
WHC at 0, 0.3 and 15 bar	***Pesticide Factors***
Antecedent soil moisture	Soil and thatch sorption coefficients (K_{oc})
Turf density (shoots/dm^2)	Foliar and soil half-life values

Table 1. Field and Chemical Parameters Collected for Runoff Model Refinement.

<u>Runoff Plot Establishment and Design</u>

The turf runoff plots will be established during the spring of 2003 with initial runoff collection beginning in the summer of 2003. The field plot design, as shown in **Figure 1**, consists of three replicated plots for each turf management regime outlined in **Table 2**. Turf maintenance parameters of relevance include mowing height and frequency, irrigation amount and frequency, fertilization and pest control, aeration and thatch management. The turf will be established and managed according to practices recommended by the USGA for warm-season fairways or MSU Extension guidelines, as appropriate. Three untreated control plots, consisting of existing native grass and broadleaf species are incorporated into the design to determine background losses of nutrients. Metal boarders or equivalent will be installed around the plot to delineate the treated areas and to prevent adjacent runoff from entering the plots. Runoff from the plots will be measured using15-cm H-type flumes and ISCO flow meters and auto-samplers.

Plot dimensions will vary depending on the purpose of the study: *Scalability* relationships between treated area and runoff will be determined using three plots ranging in size from 12 x 30-ft to 40 x 125-ft (**Table 2**). All of the scalability plots will be planted in Tifway (419) hybrid Bermuda with three plots of each dimension being managed as either fairway- or residential-type turf. The effect of grass species on runoff will be determined using 12 x 30-ft plots only. Differences in management regimes can be made between plots of similar size.

Contaminant Runoff During Simulated Rainfall Events

Runoff samples will be collected at specific intervals (e.g., 24, 168 and 336 hours after application) using rainfall simulators (Senninger Wobbler™ irrigation nozzles). Simulated rainfall intensity will be ca. 1-inch per hour. Runoff events resulting from natural rainfall will not be sampled but three runoff plots will be instrumented and their runoff measured continuously so that hydrographs can be constructed and used to estimate contaminant losses due to natural rainfall events. This latter arrangement is necessary due to the high cost that would be associated with the sampling and analysis of plots of this size and number.

Analytical Methods

Pesticides: Direct-injection, liquid-liquid partition or solid-phase extraction coupled with High Performance Liquid Chromatography (HPLC) using UV-Vis detection and/or Gas Liquid Chromatography using electron capture detection (ECD) or Mass Selective Detection (MSD) techniques will be used, as appropriate.[3]

Dissolved-phase nutrients (nitrate-nitrogen; ammonium; phosphate) will be determined using ion chromatography using EPA Method 300.1.

Total Kjeldahl nitrogen (TKN) and total phosphate will be determined first by filtering the water through a 1-µm glass fiber filter followed by digestion and detection by auto-analyzer or inductively coupled plasma (ICP) spectroscopy, as appropriate, using methods outlined by Gaudreau et al. (2002).

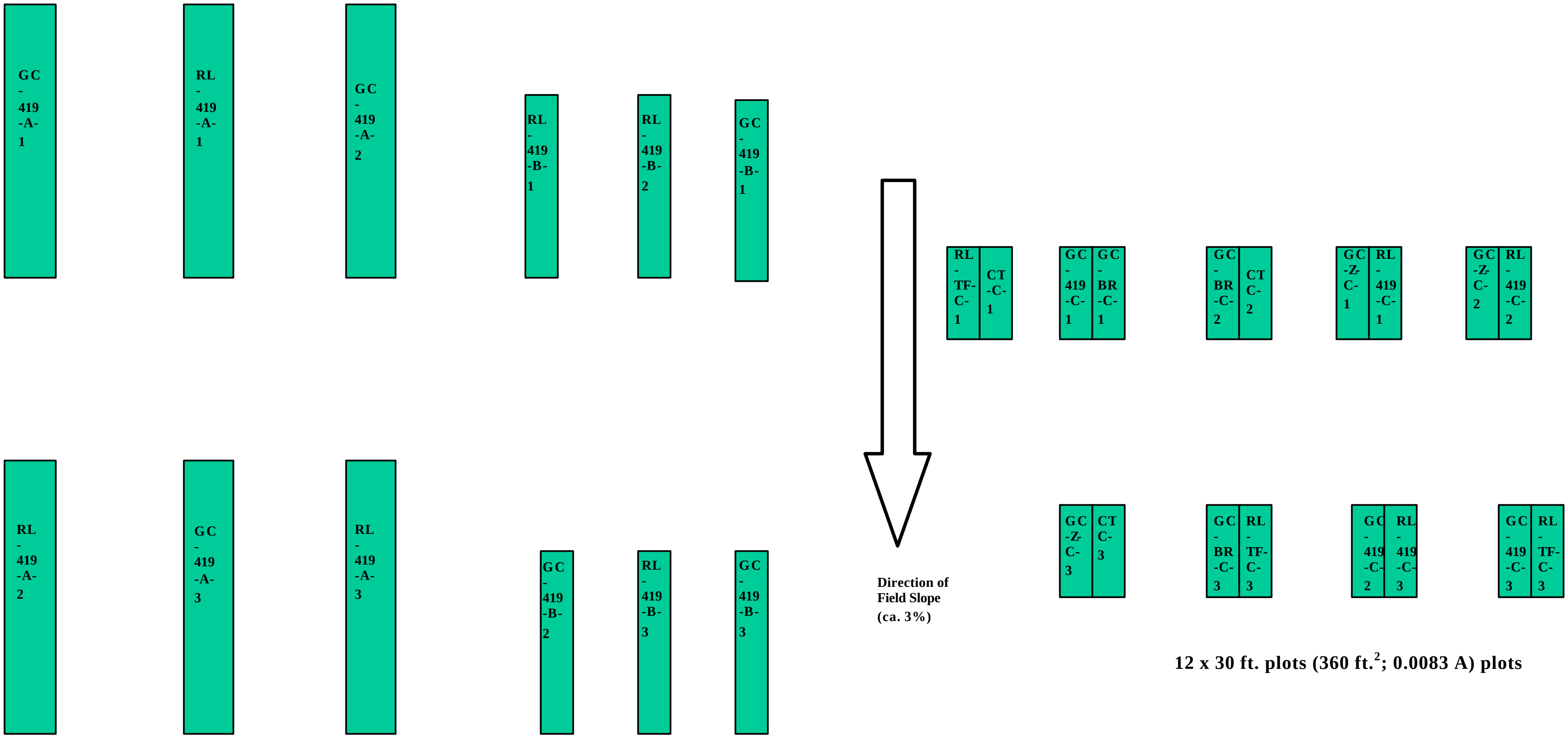
Anticipated Problem No. 1: Reliance upon natural rainfall to generate runoff result in sporadic and erratic results due to lack of control over the timing and intensity of rainfall.

How Problem is Being Addressed: We are using simulated rainfall to generate runoff at prescribed intervals after application and at known intensity.

[3] The actual method(s) used will ultimately depend upon the pesticides that are included in the study during protocol development. Protocol development is underway as part of the larger turf umbrella project and will be completed by early spring of 2003.

Maintenance Regime	***Grass Species***	***Establishment Method***	***Plot Size(s)***	***Mowing Height & Frequency***	***Watering Schedule***	***Fertilization Schedule***
Golf Course Fairway <u>Trt. Codes</u>:* GC-419-A 1-3 GC-419-B 1-3 GC-419-C 1-3	Tifway 419 Bermuda	Sprigging	(A) 40 x 125 ft (B) 20 x 80 ft (C) 12 x 30 ft	0.6 inches 3 to 5 times/wk. By reel mower	1-in./wk.	Early March: 10 lbs of 15-5-10 with 0.92% Oxidiazon (Ronstar)/1000 ft^2 (1.5 lbs of N, 0.5 lbs P, 1.0 lbs of K) Summer: 1.5 lbs N from NH_4NO_3/1000 ft^2 applied May 1, June 1, August 1, Sept 1. Early Fall: 10 lbs/1000 ft^2 of 5-5-20 P and K added per soil tests.
Golf Course Fairway <u>Trt. Code</u>: GC-BR-A 1-3	Tifway 419 Bermuda Over-Seeded With Perennial Rye	Sprigging of Bermuda. Over-Seeding with rye on Oct.1.	(A) 12 x 30 ft	0.6 inches 3 to 5 times/wk. By reel mower	1-in./wk.	Same as above.
Golf Course Fairway <u>Trt. Code</u>: GC-Z-C 1-3	Meyer zoysia	Sod	(C) 12 x 30 ft.	0.6 inches 3 to 5 times/wk. By reel mower	1-in./wk.	Same as above.
Residential Lawn <u>Trt. Codes</u>: RL-419-A 1-3 RL-419-B 1-3 RL-419-C 1-3	Tifway 419 Bermuda	Sod	(A) 40 x 125 ft (B) 20 x 80 ft (C) 12 x 30 ft	2 inches 1 to 2 time/wk By rotary mower.	As needed to maintain vigor	April 15 1.5 lbs/1000 ft^2 13-13-13 (1.5 lbs of N, 1.5 lbs P, 1.5 lbs of K) Summer 1.5 lbs N NH_4NO_3 /1000 ft^2 Applied June 15, August 15 Fall: 10 lbs of 5-5-20 applied Oct 1st. P and K added per soil tests
Residential Lawn <u>Trt. Code:</u> RL-TF-C 1-3	Rebel 3 Tall-Fescue (heat/drought tolerant)	Seeding at 8-10 lbs/1000ft^2	(C) 12 x 30 ft	3-inches 1 time/wk by rotary mower	As needed to maintain vigor	Early Fall: 2 lbs/1000 ft^2 13-13-13 (2 lbs of N, 2 lbs P, 2 lbs of K)
Control <u>Trt. Code</u>: CT-C 1-3	Existing grass and broadleaf species	Not Applicable	(C) 12 x 30 ft	2 inches 1 time/wk By rotary mower.	Same as above	Native fertility, no additional nutrients added. Plots used for background nutrient controls.

Table 2. Proposed Establishment and Maintenance Regimes Used to Determine Scalability, Grass-Species and Management Effects on Nutrient and Pesticide Runoff from Warm-Season Golf Fairways and Residential Turf.



40 x 125 ft. (5,000 ft.^{2}; 0.1 A) plots

20 x 80 ft. plots (1600 ft.^{2}; 0.037 A) plots

Legend:

GC = Golf Course fairway
RL = Residential Lawn

419 = Tifway (419) Hybrid Bermudagrass
BR = Bermuda over-seeded with Perennial Ryegrass
Z = Myer Zoysia
TF = Rebel 3 Tall Fescue

Example:
RL-419-A-1 = Tifway (419) Hybrid Bermuda in plot size A (40 x 125 ft) managed to simulate a Residential Lawn, Replication 1.

Figure 1. Proposed Runoff Plot Layout for Scalability-, Grass Species- and Turf Management-Comparisons.

Anticipated Problem No. 2: Background levels of nutrient runoff may interfere with accurate determination of transport rates of applied fertilizers.

How Problem is Being Addressed: Our field plot design includes three non-treated control plots that will allow the determination of background nutrients with each simulated runoff event.

Objective 2: Using results from Objective 1 to refine pesticide (PRZM) and nutrient (RZWQM) runoff model estimates for warm-season turf management regimes.

The first step in model calibration is to adjust model output to match the actual movement of water across the plots at the different rainfall simulation events. This hydrological calibration involves determining the timing of first runoff event and total runoff volume for the various warm-season turf scenarios under investigation. Once water movement across these plots has been accurately portrayed, chemical concentrations for pesticides and nutrients will be addressed. Dr. Don Wauchope of the USDA-ARS will perform the pesticide calibrations. Dr. Alton Johnson of Alcorn State University will perform the nutrient modeling and assist in characterizing the spatial variability of the hydrological properties of the soil at the field site.

Anticipated Problem No. 3: Soil properties and fertility are heterogeneous by nature. This is especially true for hydrological properties affecting the movement of water. This variability can significantly affect the precision and accuracy by which runoff estimations can be made.

How Problem is Being Addressed: Our study design (**Figure 1**) includes three randomly placed replications per turf management regime that will assist in assessing the variability in runoff processes.

Objective 3: Compile turf-relevant hydrological parameters and contaminant transport rates for each turf maintenance regime/grass species into database for use by regulatory agencies and environmental engineers/scientists.

The runoff parameters of interest include transport rates, turf-relevant runoff curve numbers, pesticide-turf extraction coefficients, site-specific fate parameters such as soil and thatch sorption coefficients, soil and thatch degradation rates, and management histories for the various turf scenarios investigated in this study. This information will be compiled in an electronic database (e.g., EXCEL), as batch-files for PRZM-EXAMS, and in peer-reviewed publications and reports. This information will be transferred to the target audience in the manner described in the ***Information Transfer Plan***.

Research Facilities

Field investigations will be conducted on turf plots to be established during the spring of 2003 at the Mississippi State University Black Belt Branch Experiment Station near Brooksville, MS. This site has been used to determine pesticide and sediment runoff from various cotton (Webster and Shaw, 1996; Blanche, 2001) and soybean (Baughman et al, 2001) production systems. The underlying soil is a Brooksville silty clay (fine montmorillonitic, thermic Aquic Chromudert; 3.2% OM, 6.3 pH) with a hydraulic conductivity = 5 mm/h. The runoff plots are equipped with 15-cm H-type flumes. Simulated rainfall (2.5 cm/h) is applied using wobbler irrigation heads (Senninger Irrigation Inc.) mounted to 3-m risers that are spaced 3-m apart. Runoff samples are collected into glass vessels at predetermined runoff volumes using an Isco Model 3700 auto-sampler controlled by an Isco Model 4230 flow meter. A Campbell Scientific weather station measuring rainfall, air temperature, relative humidity, solar irradiance and wind speed is in operation at the Brooksville runoff site.

(13) Related Research

Relation to Completed and On-Going WRRI-Funded Research

Previous WRRI-funded research has supported the measurement of agrochemical runoff from cotton (Baughman et al., 2002) and soybean (Webster and Shaw, 1996) production systems. Through this research, best management practices (BMPs) that meet the specific needs and growing conditions of Mississippi agriculture, such as vegetative buffer strips (Murphy and Shaw, 1997; Blanche, 2001), have been developed. This information was necessary to assess the role of NPS agricultural runoff in contaminating Mississippi's surface waters and to reduce these impacts through BMP development. Similar information is now needed to address non-agricultural runoff of nutrients and pesticides from golf courses and residential lawns.

Literature searches conducted using the *Water Resources Science Information Exchange* (WRSIC) system did not identify any WRRI-funded projects of the nature and scope described in this proposal. To the best of our knowledge, this is the only project of its kind where side-by-side comparisons of nutrient and pesticide runoff from differently managed warm-season grasses are being conducted for the purpose of improved turf runoff modeling and the development of a regional database for use by regulators and environmental scientists in the Southern Atlantic-Gulf region.

Relation to Turf Chemical Runoff Research

The use of small plots for runoff studies is currently favored by researchers. Small plots allow multiple treatments to be examined without utilizing large blocks of land, which makes it relatively easy to develop plots with uniform field conditions (slope, soil type). The use of small plots also avoids the need to apply large volumes of water to generate runoff, and eliminates complications associated with sampling large volumes of runoff. Unfortunately, the use of small plot data to assess the performance of field-scale models to predict turf chemical runoff has produced inconsistent results. Much of the inconsistency appears to be related to the inability of the curve-number method to successfully provide estimates of small plot runoff. Reasonable predictions of the pesticide concentration in turf runoff have required extensive adjustment of the curve number (CN) in small plot modeling efforts (Wauchope, et al., 1990; Durborow et al., 2000).

To accurately simulate runoff from small, dense turf plots in Georgia, Durborow et al. (2000) found it necessary to use a CN recommended for a poor stand of grass grown in much finer textured soil than was actually present at the site. The difference in the CN number specified for the site by the NRCS (Technical Release 55, Urban Hydrology for Small Watershed, CN = 61) and the CN number that was actually used in the calibration of the model (CN= 91) was substantial. To put this into perspective, Haith (2001) reported that changing the CN at a Kentucky site from 58 to 62 increased the predicted runoff at the site by 131% (i.e., from 2.9 to 6.7 mm). In another study conducted at the Georgia site just mentioned Ma et al. (1999) compared actual and predicted runoff using the curve-number method option of the OPUS Model. They found the hydrological component of this model could not adequately predict individual plot runoff. They did however report that there was relatively good agreement between predicted runoff and the mean amount of runoff from all 12 plots at the site. Ma et al. (1999) noted that seemingly uniform small plots can have substantially different hydraulic properties, which the curve number method does not consider. They also stated that one of the reasons why the curve number method works well at the field scale of level of resolution is because spatial differences in hydraulic properties tend to cancel out one another at that level of resolution. Haith and Andre (2000) have proposed a set of

CN for various turf situations. Using runoff data from six different turf sites they were able to demonstrate that use of their CN values explained 78% of the observation variation in runoff. No attempt was made, however, to examine the relationship between the amounts of runoff predicted by their CN approach and size of the plot size being evaluated. This information is needed to examine the scalability of their turf CN approach; "scalability" issues have been found by the USEPA and key turf stakeholders to limit the utility of turf runoff models (Nett, 2002). *Our proposed study is designed to determine the scalability of runoff results from turf managed as either golf course fairways or home lawns.*

Investigations by Pennsylvania State University researchers have shown that grass species can impact the timing and extent of runoff from turf (Linde et al., 1995). Linde et al. (1995) found that runoff from mature perennial ryegrass (*Lolium perenne* L.) plots occurred sooner and in greater volumes than from creeping bentgrass (*Agrostis stolonifera* L. (Huds.)). This was attributed to the stoloniferous nature of bentgrass as compared to ryegrass that has a bunch-type growth habit. The dense mat of stolons is thought to increase hydraulic resistance and water-holding capacity, thereby allowing greater water infiltration in bentgrass, slowing runoff. These differences could be used to refine environmental risk assessments as bentgrass increasingly appears to be the turfgrass of choice for golf courses in the mid-Atlantic region. While differences in root distribution in warm-season turf type have been shown to affect nitrate leaching (Bowman et al., 2002), species effects on pesticide runoff have not been adequately investigated. Determination of differences in agrochemical runoff for different grass species was recently found to limit the utility of turf runoff models by the USEPA and key turf stakeholders (Nett, 2002). *Our study is designed to determine warm-season grass species effects on turf chemical runoff.*

(15) Training Potential

This project will support the education and training of one Ph.D.-level student and two to four undergraduate students. For a Ph.D. student interested in the environmental sciences, this project will allow them to gain valuable hands-on experience in the field and laboratory. The graduate student will play an important role in this project and will interact with regulatory authorities, modelers, environmental chemists, industry representatives and water quality consultants, among others. The student will be engaged in a project that addresses an area that is anticipated to gain considerable importance over time, namely, addressing environmental issues related to turf maintenance and production. This project will involve a blend of field, laboratory and modeling techniques that should prepare the student for successful employment in the environmental sciences arena.

Information Transfer Plan

The problem to be addressed in this work is the improved estimation of nutrient and pesticide runoff from managed turfgrass. Upon successful completion of this project, turf runoff scenarios for golf course fairways and residential lawns grown using warm-season grasses relevant to the South Atlantic-Gulf region will be made available to the target audience of this work (i.e., regulatory and environmental engineers/scientists charged with assessing health risks and environmental impacts associated with non-point source runoff of nutrients and pesticides in surface waters).

The turf runoff model scenarios and other results of this project will be disseminated through referred journals (e.g., the *Journal of Environmental Quality, Pesticide Management Science Journal, Weed Science*), WRRI annual reports, MAFES experiment station bulletins, oral/poster presentations at regional (Southern Weed Science Society) and national (American Chemical Society; American Agronomy Association, Weed Science Society of America) meetings, water quality conferences, and at quarterly meetings held by the environmental modeling working group (EMWG) hosted by the USEPA.

Once the turf runoff scenarios have been improved, our plans are to host a training workshop on improved turf runoff modeling for interested individuals and regulatory authorities. The training session will be held in conjunction with the EPA's quarterly EMWG meeting held in Washington, DC. Similar training events have occurred in association with these meetings and would provide an excellent avenue for dispersing results of this project since many of the nation's top environmental modelers regularly attend the EMWG meeting. Depending on the response to the workshop, additional workshops might be held as part of the EMWG group or as part of symposium on turf environmental issues hosted by the Agrochemicals Division of the American Chemical Society in 2004/2005.

APPENDIX 1

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Literature Cited

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